INCREASED STIFFNESS OF VEHICLE STRUCTURE IN ACCIDENT

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part application of co-pending international application number PCT/DE 96/02120 (WO 97/18984, EP 0869878 B1) filed Nov. 7, 1996 and claiming the priority of DE 195 43 706 A1 filed Nov. 17, 1995. is revised and refiled.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to vehicle doors and, more particularly, to interengaging assemblies which structurally integrate all vehicle doors, when closed, with the vehicle roof, both side rails (sill portions) arranged along the vehicle floor, all post sections (pillar portions) and the flanges of door apertures of a vehicle body thereby distributing energy to all those vehicle members, lowering stress thereof, preventing passenger ejection and enhancing survival chance in the event of any collision (front, side and/or rear collision) or rollover.

2. Discussion of the Prior Art:

In order to formulate in single terminology a generalized definition for the proper term is presented:

Definition:	**Proper Term:**
"*series-connected doors*"	doors of one vehicle side are series-connected
"*girder*"	panel, shell, beam etc. according to FEM and Technical Mechanics
"*window-guide elements*" of vehicle doors	window-guides **6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB**
"*door cavity*"	space between the outer and inner panel of the door
"*door detachment*"	vehicle door becomes detached from the vehicle body
"*mating parts of interengaging assembly*	mating parts of an interengaging assembly such as key & receptacle, hook & recess, hole & key or hook & rod
"*engaging hole*"	aperture, slot, oblong hole
"*vehicular couple*"	two mating vehicle members, such as vehicle door & vehicle roof, vehicle door & side rail, vehicle door & flange (transition region) of vehicle body, vehicle door & post section/s, vehicle door & vehicle door in engagement in the event of any collision and/or rollover

It is known in the prior art to provide interengaging assemblies to engage and/or clamp the vehicle door with the mating vehicle members, when the vehicle door is in closed position, thus distributing energy, lowering stress whilst enhancing survival chance only in the event of either mid-front collision or side collision of type U2, one of four types shown in **Fig.** 13.

However, all these conventional configurations do not take into account the failure of passenger protection due to the following problem cases in conjunction with disengagement of the mating parts of interengaging assemblies from each other in the event of all types of real collision (any real collision) or real rollover:

- **A** Load cases **I to V** according to Technical Mechanics/FEM in real front, side and rear collision;
- **B** Wrong assumption of the prior art for the purpose of idealizing a general side energy S or S_1 to a single energy S_x or S_{x1};
- **C** Analogy between the state of non-contact and disengagement;
- **D** Constant, small contour-clearance and assembly tolerance zones;
- **E** Large clearances of interengaging assemblies;
- **E1** The first inventions of interengaging assemblies, huge production costs and fatal injury in real collision due to large clearances;
- **E2** Large deformation of vehicle structure or door **8. 8B** in real collision;
- **E3** Large deformation of side rail **18** in real collision;
- **E4** Large deformation of upper door frame **8.17** and vehicle roof **17** in real collision;
- **E5** Intrusion of vehicle roof **17** in vehicle body **20** on real rollovers; and
- **E6** Clamping assemblies or adjustable interengaging assemblies to resolve problem case **E.**

Problem case **A**: In order to idealize an impact force $2F_1$, shown in **Fig.** 10A, imposed on a vehicle structure the following assumptions must be specified:

- let the vehicle structure be idealized by two symmetric vehicle halves subjected to an front impact force 2F along the centre line.

Load case **I** in z-y plane in **Fig.** 5: The moment $M_x = H*h$ about the x-axis is replaced by a pair of forces $H_A = (H*h)/l$ with the lever arm of l. Employing the equilibrium condition for moments two forces of reaction are obtained: $V_A = (V*l_C)/l$ and $V_B = -V_A + V$. Acting in z-direction with respect to the sign are three shear forces: -V, $(H_A + V_A)$ and $-(H_A + V_B)$. Under load of these forces the vehicle side, comprising all post sections, series-connected doors **8, 8B** reinforced by impact elements and interengaging assemblies of those doors and post sections, is subjected to the bending moment along the y-axis.

Load case **II** in z-x plane in **Fig.** 6: The force V exerts bending moment M_{zx} along the x-axis and rotating moment $M_y = V*b$ about the y-axis acts as torsional moment along the vehicle side.

Load case **III** in x-y plane in **Fig.** 7: The A-post section is under load of rotating moment $M_{xy} = -H*b$. The vehicle side is subjected to bending moment M_{xy} along the y-axis and buckling force H.

Subjected to the total stress of bending moments M_{zx}, M_{xy}, M_{zy}, buckling force H and torsional moments M_z, M_y in the load cases **I to III**, the vehicle side, shown in **Fig.** 8, is deformed in real front collision.

By reversibly arranging the series-connected doors **8, 8B** the same load cases are obtained for real rear collision.

Load case **IV** in x-y plane in **Fig.** 9: Under load of side impact energy S at impact angle α 27° according to FMVSS 214 or in the event of real side collision the vehicle side is subjected to bending moment M_{xyS} along the y-axis and lateral force S_y.

Load case **V** in z-x plane in **Fig.** 10: Under load of side impact energy S at impact angle γ or in the real side collision against a tree or highway column **22**, shown in **Fig.** 10A, 13, the vehicle side is subjected to bending moment M_{zxS} along the z-axis and lateral force S_z.

The total stress consists of the stresses in load cases **IV** and **V**.

Problem case **B**: The majority of the prior art is governed by the following assumptions:

- let clearances between mating parts of an interengaging assembly be neglected and
- let the load cases **IV** and **V** be idealized to a lateral energy S_x, shown in **Fig.** 9, or S_{x1}, shown in **Fig.** 10A, imposing on the *centre* of vehicle door, illustrated as collision type U1, shown in **Fig.** 13, despite four collision types U1 to U4 and the collision type U2 having the highest percentage of severe and fatal injuries. Nevertheless, car manufacturers and suppliers world-wide have adopted this idealized S_x or S_{x1} in inventions e.g. U.S. Pat. No. 4,307,911, U.S. Pat. No. 5,806,917, U.S. Pat. No. 5,518,290, whose shortcomings are mentioned in the following problem case **E2**.

Problem case **C**: Ref. to **Figs.** 11, 12 both end coils of compression-coil spring **19** are guided by two spring seats **19.1**. Their utmost outer nodes KN_1 and KN_{End} (not drawn) rest against both stops **19.3**, where i represents the number of coils. To survey the rolling behaviour of end coil **19** on the lower spring seat **19.1** the end coil is idealized in elements by supporting springs in reference to the nodes and by the threshold value of the distance in the "state of rolling" s < 0.1 mm. **Fig.** 12 illustrates the rolling behaviour in regard to the FEM data and test results marked with **M** in dependence on F_z = -790, -1000 and -3000 N:

- According to test results KN_2 to KN_5 roll on the spring seat at F_z = -790 N, but in the state of non-contact at F_z = -1000 and -3000 N.
- According to FEM data the nodes in the following states are in dependence on F_z:

F_z	State of contact	State of rolling
-100	KN_1, KN_{15}, KN_{17}	KN_1 to KN_3, KN_{10} to KN_{18}
-250	KN_1, KN_{19}, KN_{20}	KN_1, KN_{15} to KN_{23}
-1415	KN_1, KN_{17}, KN_{19}, KN_{20}, KN_{30}, KN_{31}, KN_{33}, KN_{34}	KN_1, KN_{15} to KN_{35}

The state of contact (engagement) of mating parts of interengaging assemblies, idealized by nodes of the rolling end coils and mating elements of the spring, can be transformed into the state of disengagement, when the force increases.

Problem case **D**: Recently in automotive industry, great efforts have been made to achieve (finish) a constant (uniform), small contour clearance between the outer door-contour "abcde" of vehicle door **8, 8B** and the door aperture of vehicle body **20**, shown in **Fig.** 5, in order to minimize flow noise and, particularly, to achieve sales success in co-operation with an overall impression of attractive design. In the state of assembly the contour clearance e.g. of AUDI ® vehicles is only 2.5 mm and of VW Passat ® 3.5 mm.
In order to meet the above-mentioned goal and to avoid rework or reject rate large assembly tolerances between the outer door-contour and the door aperture (opening) of vehicle body **20** must be designed.

Problem case **E**: The door lock **248**, rigidly attached to vehicle door **8**, and the striker **298**, rigidly attached to post section illustrated as B-post section in **Fig.** 10A of U.S. Pat. No 4,307,911 representing the prior art, is provided with locking clearances in x-, y- and z-direction, thus ensuring the state of door locking and the normal operation of vehicle door. For the purpose of preserving the constant, small contour-clearance,

- the position D_a to D_c of each key **128a to 128c**, rigidly attached to vehicle door **8**, and the position S_a to S_c of mating receptacle **158a to 158c**, rigidly attached to lower stiff panel **156** of side rail **18**;
- the position D_n of key **148**, rigidly attached to vehicle door **8**, and the position B_n of mating receptacle **198**, rigidly attached to post section,

must be provided with position-tolerances, larger than locking and assembly tolerances, in x-, y- and z-direction in order to avoid

1. interference with the locking operation of door lock **248** to striker **298** when closing vehicle door **8**;
2. expensive reworking at the assembly line;
3. customer complaints due to disturbing noises associated with the small distances of overlaying coils, representing the mating parts of interengaging assemblies, denoted as w ≤ 0.2 mm, shown in **Fig.** 11; and
4. high reject rate due to different references of coordinate system of vehicle door, finished by two to three suppliers and transported to assembly line, and of vehicle body **20**, finished at the assembly line. Huge costs are necessary to computerize design data of vehicle door and structure in data files, which must be evaluated by innovative programs to minimize those position-tolerances and reject rate, however, under the condition of the constant, small contour-clearance.

Problem case **E1**: According to the prior art the taper-formed key **148** and the mating receptacle **198** should be in engagement or form-locking connection to ensure energy-transmission from one post section to the other.
Because receptacle **198** and striker **298** are formed together in one piece, an adjustment of receptacle **198** changes the position of striker **298** to the door lock **248** as well as the clearance therebetween, which becomes too large or small. In order to properly latch and lock the vehicle door to vehicle structure the "interengaging" assembly is provided with large tolerance zones, thus violating the condition of the aforementioned feature.
When a vehicle is laterally crashed by a truck, the key **148** can disengage from mating receptacle **198** due to large clearance so the remaining energy totally deforms the vehicle door, whose intrusion can fatally injure the driver.

According to the prior art shown in **Fig.** 1A, contour tongues **16.1** should be in engagement with contour grooves **16.2** in order to integrate vehicle door **8, 8B** into side rail **18**, vehicle roof **17** and B-post section in side collision. Without "interengaging" assembly of the vehicle door and B-post section, the normal operation of vehicle door would be possible if the outer door-contour "abcde" were square. Regarding the recent contour design, shown in **Figs.** 5 and 18, the line "ab" is generally curve-shaped, line "bc" of front door upwardly inclined ($\beta > 90^0$) or generally curve-shaped and line "bc" of rear door generally S-shaped, so contour grooves **16.2** would interfere with contour tongues **16.1** when closing the vehicle door. Furthermore, to sustain large impact energy it is necessary to reinforce the wide contour groove by an element which, unfortunately, can't be attached to the narrow upper region of door frame **8.17**.

According to the U.S. Pat. No. 3,819,228 a bulky "engaging" bolt rigidly attached to a stiff inner panel of vehicle door **8** projects through a hole of a stiff element attached to side rail **18** when the door is in closed position. The problem of large tolerance zones remains unresolved. Moreover, the overall stylish impression spoilt by a bulky "engaging" bolt will, doubtless, not be beneficial to sales. When stepping in or out of the vehicle body while cleaning or repairing, the person can injure himself when stumbling over this bulky bolt. When closing the door the danger of damage to clothing and injury to passengers, particularly when it is dark, is apparent.

Problem case **E2**: Under the load of force F_1, shown in **Fig.** 10A, in an approx. 30^0 inclined, offset front collision against another car the vehicle structure, totally deformed, is deflected, in great extent, in the opposite x-direction and in the y-direction thus resulting in disengagement of the catching hook **148**, rigidly attached to the impact beam **1, 1B** of driver-door, and the door lock **248** from the mating recess **198** and striker **298**, all of which are rigidly attached to the B-post section, respectively, in association with the reduction of the distance between the A- and B- post section from 860 mm to 490 mm in the y-direction

and the collapse of passenger protection. Later on, the remaining energy totally deforms the driver-door too. If the car rolls over, the driver would be ejected thereout.
In a real side collision of another car into a tree, great energy totally deformed the vehicle side whose intrusion fatally injured both passengers. Obviously, the lateral force, deviating from the idealized force S_{X1}, could not force catching hook **148** to penetrate into recess **198** in order to define an "interengaging" assembly.
Both real accidents resulting in severe/fatal injuries verify the shortcomings of any patent valid only for survival chance under load of an idealized force S_{X1}, denoted by arrow A in Fig. 1 of U.S. Pat. No. 5,518,290. Taken as given, the mid region of door is secured to the B-post section by the "interengaging" assembly in an "idealized" accident, the upper, lower door frame **8.17, 8.18**, the vehicle roof **17** and side rail **18** are overstressed due to lack of interengaging assemblies. Moreover, problem cases **E3 to E6** remain unresolved.

As exemplified by U.S. Pat. No. 4,676,524, a pair of vertically supporting window-columns, rigidly mounted in both vehicle doors **8** of a convertible car is in abutting, "engaging" relationship with both termini of upper member of cowl, when both vehicle doors are in closed position, owing to a pair of "interengaging" assemblies, each of which consists of

1. a receptacle of the terminus of the upper member and a locking mating tip of key of the window-column pressing therein in the first embodiment; or
2. a king-size hole of the terminus of the upper member and a mating key of the window-column having a mushroom-shaped head being in free connection therewith in the second embodiment

for the purpose of enhancing survival chance on rollover.
When the convertible car rolls over,

1. great shear force fractures each locking tip of the key; or
2. great impact energy totally deforms each "interengaging" assembly, whose key and king-size hole are in disengagement,

thereby totally deforming the cowl and pair of window-columns.
The stiffness of an open roof of a convertible car, merely supported by a pair of post sections in force-locking or free connection with one pair of small-size window-columns, is

- very low, thereby resulting in fatality on a real rollover thereof;
- lower than that of a rotatable, stiff rollover bar;
- far lower than that of the closed roof **17** supported by two pairs of post sections and
- substantially far lower than that of the closed roof **17** strongly supported by three pairs of reinforced post sections.

Problem case **E3**: Due to great energy in a real side collision against column **22** of a central barrier, shown in **Fig.** 10A, 13, on a highway

- large deformation of side rail **18** and rear section of a vehicle, opposite to x-direction, caused the disengagement of the driver's less deformed vehicle door **8** from vehicle structure and later on
- the vehicle rolled over three times across the highway and down-hill, thus totally deforming vehicle structure, doors **8**, tailgate-door **8T**, out of which both rear passengers were hurled, and, alternately, opening and closing both vehicle doors **8**, out of which both front passengers were hurled out.

Grass **70** clamped between each post section and each vehicle door **8**, shown in **Fig. 8**, was an evidence for the alternate opening and closing of both vehicle doors **8** during the rollovers.

In a side collision of a car into a tree great energy totally deformed vehicle door **8** whose intrusion severely/fatally injured the passengers.

In a collision of another car into a hill great energy totally deformed the right side rail **18** thus resulting in the disengagement of the door lock **248** and, if provided, interengaging assemblies too and later on totally deforming vehicle structure during rollover. The driver was hurled out of this car.

Problem case **E4**: In front collision or crash test impact energy deforms, in general, upper door frame/s **8.17** outwards and vehicle roof **17** upwards, thereby creating a gap „o", shown in **Fig.** 8, and preventing front vehicle door/s **8, 8B** and/or vehicle roof **17** from transmitting energy to vehicle body **20**.

Three different states of deformation are reproduced in three crash tests, conducted by ADAC, of the German vehicles of the same type 40 % offset crashed at the same speed of 50 km/h against

- a very stiff barrier,
- a deformable barrier and
- another vehicle of the same type

because the uniform load, deformable property of two colliding masses, impact condition etc. are different. The gap „o " in three different sizes, shown in **Fig. 8**, verifies the above-mentioned thesis of non-transmission of energy.

In side collision impact energy deforms, in general, upper door frame/s **8.17** inwards thereby inflicting injuries on head.

Problem case **E5**: During the rollover of a car, impact energy totally deformed vehicle roof **17** whose intrusion severely or fatally injured both front passengers, whose heads were, definitely, crushed by falsely deployed airbags, and the remaining energy totally deformed vehicle body **20** and doors **8, 8B, 8T, 8x**.

Problem case **E6**: Responsive to problem case **E**, a clamping assembly illustrated in **Fig.** 1B comprises

- a stiff hook of stiff ledge **25.2** rigidly mounted to lower door frame **8.18** and
- a thin mating panel of a stiff plate **25.1**, rigidly attached along sill rail **18**, serving as a site of predetermined fracture.

In excess of predetermined value in real side accident, the mating parts **25.1, 25.2** of interengaging assemblies are in the state of clamping to ensure the permanent engagement of lower door frame **8.18** with sill rail **18** in order to resolve the problem of passenger ejection. Load cases **I to III, V** and problem cases **E2 to E5** remain unresolved. Furthermore, there is no space to house both mating parts **25.1, 25.2** in vehicle roof **17** and upper door frame **8.17** subjected to lateral load F_o in real accident. The lack of interengaging assemblies became obvious on the rollover of a sport car, which plunged seven meter downwards and crashed with vehicle roof **17** at a lower level of an underpass in Wiesbaden City thus totally deforming vehicle roof **17**, body **20** and both upper door frames **8.17** during rollover, where the remaining energy was transmitted through both head rests, integrated into the respective seatbacks, to the vehicle floor, thereby reducing the AIS of both passengers. AIS is an international acronym of Abbreviated Injury Severity ranging from 0 (no injury) to 6 (fatality).

Responsive to problem case **E**, adjustable and/or latching mechanisms are provided for interengaging assemblies, whose adjustable and/or latchable keys are bolted to the B- or C-post section, facing the termini of both reinforcing beams **1, 7** or **1B, 7B**, and whose mating receptacles are arranged thereto. Both plates **5.1, 5.2** of each hinge of vehicle door are provided with a rivet serving as key and an oblong mating hole. Owing to this feature load cases **I to IV** are resolved, but load case **V** and problem cases **E3 to E5** remain unresolved.

Evidently, due to load cases **I to V** and all problem cases **B, E, E1 to E5** "interengaging" assemblies of the remaining prior art are unsuitable for the purpose of energy-transmission and distribution by means of the integration of vehicle doors **8, 8B, 8T** into the vehicle body **20**, in conjunction with five tolerance zones proposed by U.S. Pat. No. 5,297,841, U.S. Pat. No. 4,307,911 and eight tolerance zones proposed by U.S. Pat. No. 5,806,917.

SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is to overcome the deficiencies of the prior art by providing engagement for interengaging assembly having large clearances, which are necessary in car manufacturing and door assembly, in order

- to protect passengers against ejection from the vehicle body and/or intrusion of vehicle member and
- to increase the vehicular stiffness

in the event of any collision and/or rollover. These interengaging assembly are arranged to the corresponding vehicular couples (vehicle member & mating vehicle member).

This principle and other objects of the present invention are accomplished by the following features (proposals):

- minimum tolerances by installing and adjusting the engaging keys from outside to tightly mate the receptacles thereby ensuring the connection of the doors with all vehicle members of vehicle body **20** such as post sections, vehicle roof **17**, flange **21**, a pair of side rails **18**, fastened to vehicle floor, in any collision and/or on rollover;
- interengaging assemblies with adjusting mechanisms such as holes & keys **15.1 to 15.5a**, **15.7**, **15.8**, hooks **15.6** & reinforcing rod **17.1d** and holes & keys **30 to 37**, shown in **Fig.** 1, 3, 3A, 4, 4A and 14 to 18;
- window-guide elements to accommodate the engaging parts;
- space-saving, inexpensive design for engaging parts;
- arrangement of interengaging assemblies of a vehicular couple in at least two operating planes thus making the strict restriction of minimum tolerances less significant;
- arrangement of an U-shaped extension member having keys in the common post section of the series-connected vehicle doors, whose holes mate with the keys to ensure the engagement owing to constrained deformation thereof.

Despite the failure of the prior art in the event of real side collision any modification and extra design for survival chance in real collision and/or on rollover will generate costs, R&D expenses and weight due to the use of other inventions.

Summary of the advantages of the present invention:

A) saving labour-time by installing and adjusting engaging parts from outside the vehicle body.

B) low reject rate.

C) space-saving, inexpensive design.

D) dissimilar operating planes or at least two operating planes for each vehicular couple to ensure the engagement of its interengaging assemblies in association with energy absorption due to load cases in three different planes. **Figs.** 14 to 18 illustrate *a single vehicular couple*: window-guide element & B-post section with the interengaging assemblies: keys **34** & holes in z-x plane acting as the first operating plane, however, interengaging assemblies: keys **32, 33** & holes in z-y plane acting as the second operating plane. The specification is changed from the minimum tolerances of "narrow" to permissible tolerances of "far less narrow", thus cutting costs and time associated with less adjustment work to reduce large clearances thereto. This feature of dissimilar operating planes is applicable too for both interengaging assemblies: holes & **15.1, 15.2a** and **15.2, 15.3** and **15.4a, 15.5** etc., shown in **Fig.** 3. A row of the same keys is operative in dissimilar operating planes by arranging a number of the same keys **15.1** to the generally inclined A-post section or of keys **33** to the generally inclined B-post section. In reference to the global xyz coordinate system the key **15.2a** & hole is operative in an inclined plane.
Because the hinge bolts of the front and rear doors have an operating direction in z-axis the arrangement of interengaging assemblies: holes & keys **31, 36** to one operating plane is sufficient. However, any additional arrangement of holes & keys **30, 35** improves the engagement of vehicle mating parts and substantially decreases severe/fatal injuries in any real collision.

E) minimizing the R&D work by reducing FEM calculations, crash tests and by saving material due to the arrangement of interengaging assembly in different operating planes.

F) passenger protection for all collisions by a single construction, manufacturing, testing expenditure, assembly and material supply.

G) exploitation of the flange **21, 21T, 21h, 21x** of vehicle body **20** provided with sound-proofing material **21.10**, shown in **Figs.** 1, 17, 18, due to the sites to accommodate keys and the continuous stress curve. The enlargement of the flange to a limited extent neither impairs the overall stylish impression nor obstructs the passenger from ingress into or engress from the passenger compartment. Those edges (regions) of all post sections are defined by the dotted lines "a1", "b1", "b2" and "c1".

H) overall stylish impression. As substitutes of the bulky bolt ref. to U.S. Pat. No 3,819,228 small-size parts can be distributed in inconspicuous manner along the window-guide elements as well as flange, thus substantially ensuring the engagement of vehicular couple whilst lowering stress. Due to this feature it is possible to arrange the following keys:

- **30, 32, 35, 37** to the respective flange **21** of vehicle body **20**. In contrary to U.S. Pat. No. 3,819,228, this feature won't endanger passenger when stepping in or out, furthermore, more useful for passenger protection in side collision, particularly, according to collision types U1 and U2, shown in **Fig.** 13, as well as in front collision.
- **15.2a, 15.2, 15.7** e.g. with screws M4 to the narrow window-guide element **6.3, 6.3B** of upper door frame **8.17** to resolve the problem of the large, stiff contour groove of the prior art.
- **33, 34, 36** to the respective window-guide elements **6, 6B** and elements **6.7, 6.8** in engagement with the reinforced B-post section in two to three operating planes without obstructing the operation of the seat belt **26.1**, shown in **Fig.** 15. The fact, that no contact is made during the opening operation of series-connected vehicle doors, is demonstrated by the trajectories of both outer points of the washer and of the door edges drawn with dotted lines.
- **31** to the respective window-guide elements **6** and elements **6.6a** in engagement with the reinforced A-post section.

I) less stress to solve the problem of total deformation. By means of arrangement of interengaging assemblies of each vehicular couple in multi-operating planes and increase of vehicular couples comprising vehicle door & vehicle roof **17**, vehicle door & side rail **18**, vehicle door & post section/s and vehicle door & vehicle body **20** more vehicle members in compound construction are involved in energy absorption in different load cases in the event of any collision and/or rollover.
In co-operation with another prior art the structural stiffness reaches the maximum. Beyond doubt, the advantage of keys *2.1, 5.6* & mating holes is due to the further exploitation of the very stiff impact beams **1, 7** to house the corresponding parts. Because the other vehicular couples comprising such as vehicle door & side rail and vehicle door & vehicle roof are not equipped with interengaging assemblies this *single* arrangement of one vehicular couple in mid region of door is insufficient in the event of any collision and/or rollover, therefore endangering the passengers in the following state of deformation
 - intrusion of vehicle roof **17** into the vehicle body and of upper door frame **8.17**, thus squashing the passengers and
 - buckling of the upper portion of the A-post section, total deformation of upper door frame **8.17**, buckling of vehicle roof **17** and buckling of side rails **18**, shown in **Fig.** 8.

In order to avoid the above-mentioned state a number of holes or keys **30 to 37** is arranged to the flange **21** *above*, *below* of the impact beams **1, 7** and *therebetween.* When the *non-adjustable* rivets *5.6* of the door hinges in x-z operating plane are replaced by a number of interengaging assemblies **15.1, 15.2a, 15.4, 30, 31** in numerous operating planes, the total stress of the vehicular couples: A-post section & vehicle door along the z-axis is lower owing to stress distribution, thereby preventing, to a certain extent, the A-post section and vehicle door from total deformation and gap „o", shown in **Fig.** 8.

J) measures against passenger ejection and total deformation of the vehicle members, whereby vehicle doors are not or less deformed, in real accident ref. to problem cases **E2** to **E4**, which can solely be solved by engagement of the following interengaging assemblies governed by permissible tolerances:
 - holes & keys **15.3, 15.3a, 15.5a, 15.5** owing to U-shaped extension members **17.3, 18.3**, whose deformation causes a constrained deformation of the series-connected vehicle doors, vehicle roof and side rails;
 - holes & keys **32, 33, 34, 30, 15.2, 15.4a** of the vehicular couple comprising vehicle door & B-post section in four operating planes; *and/or*
 - hooks **15.6** & reinforcing rod **17.1d** of both vehicular couples comprising series-connected vehicle doors & side rail and series-connected vehicle doors & vehicle roof, so that the deformation of the side rail and vehicle roof causes a constrained deformation of the series-connected vehicle doors; and

by *energy transmission* into the other vehicle side by means of transverse girders **17.2, 17.2b, 17.2c, 17.2d, 18.2** of vehicle roof, side rails and all post sections facing each other, thus distributing the energy thereto.

K) passenger protection by engagement of vehicle couples in rear collision. Door detachment in rear collision occurred due to the lack of door hinges and interengaging assemblies. For the purpose of connection of vehicular members to each other the engagement of rear door **8B** with the C-post section is improved by rigidly arranging
 - element **6.5C,** adapted to the outer door-contour and having holes to receive mating keys **37**, shown in **Figs.** 14, 18, to the door frame of rear door; and
 - keys **33, 34** to window-guide element **6B.**

The features of vehicle door are, doubtless, suitable for tailgate door **8T**, sliding side door, liftgate door cargo door, trunk cover **8x**, hood **8h**, series-connected doors, e.g. three vehicle doors with four post sections of large van.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention will be described in the accompanying drawings with reference to the xyz global coordinate system::

Fig. 1 is a side view of vehicle side, body, impact beams, keys, hooks, window-guides and window-guide elements (reinforcing elements).

Fig. 1A is a cross-sectional view of a vehicle door engaging with a roof and side rail ref. to DE-OS 2162071 in side collision.

Fig. 1B is a cross-sectional view of a vehicle door engaging with a side rail ref. to EP 0423465 A1 in side collision.

Fig. 2 is a side view of an U-shaped window-guide element, the position of keys **15.7**, **15.8** and of an additional window-guide element **6.4**, **6.4B**.

Fig. 2A is a side view of an U-shaped window-guide element, the position of keys **15.7**.

Fig. 3 is a perspective view of a front stiff door frame with both window-guides, both respective window-guide elements and interengaging assemblies of the 1st embodiment.

Fig. 3A is a cross-sectional view of a key equipped with an adjusting mechanism.

Fig. 4 is a perspective view of interengaging assembly hooks & reinforcing rod of the 2nd embodiment.

Fig. 4A is a cross-sectional view of the reinforcing rod and the mating hook equipped with an adjusting mechanism.

Fig. 5 illustrates a load case I in z-y plane in front collision of vehicle.

Fig. 6 illustrates a load case II in z-x plane in front collision.

Fig. 7 illustrates a load case III in x-y plane in front collision.

Fig. 8 is a state of total deformation of vehicle at displacement v in front collision.

Fig. 9 illustrates a load case IV in x-y plane in side collision of vehicle.

Fig. 10 illustrates a load case V in z-x plane in side collision.

Fig. 10A illustrates the mating parts of interengaging assemblies ref. to U.S. Pat. No 4,307,911, both mating parts of a door lock, the general force F_1 or S_1 in the event of front or side collision and a highway column.

Fig. 11 is a view of a compression-coil spring on a lower spring seat.

Fig. 12 illustrates the projection of the end coil and spring seat in a plane, the test results and FEM data of an end coil rolling on the lower spring seat in dependence on load.

Fig. 13 illustrates four collision types U1 to U4 ref. to the research work of Institute of Vehicle Safety, a Dept. of German Insurers Association, and a highway column.

Fig. 14 is a perspective view of interengaging assemblies of the 3rd embodiment comprising a stiff front door frame having a single window-guide element and a stiff rear door frame having a single window-guide element to engage with the post sections and flange of vehicle body.

Fig. 15 is a cross-sectional view of the series-connected doors in engagement with the A-, B-post section and of the vehicle body along the line D-D in **Fig.** 14.

Fig. 16 is a side view of the series-connected stiff door frames without window pane in engagement with the B-post section according to arrow E in **Fig.** 14.

Fig. 17 is a perspective view of interengaging assemblies of the 4th embodiment comprising a stiff front door frame having a single window-guide element in engagement with the flange of vehicle body.

Fig. 18 is a side view of the flange of vehicle body provided with keys.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Ref. to **Fig.** 3 the scope of the application of the window-guide elements of vehicle door is extended to accommodate the keys of interengaging assemblies, whose mating receptacles are arranged to any (A-, B-, C- or D-) post section, flange of vehicle body, vehicle roof and/or side rail. The positions of keys and mating receptacles may be interchanged if desired.

According to the prior art a stiff door frame of vehicle door can be assembled, without door girder and reinforcing elements, from at least two impact beams provided with interengaging assemblies and at least one window-guide element **6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB**. As is customary, the window-guides **6.1, 6.2, 6.1B, 6.2B**, shown in **Figs.** 1 and 3, are made from U-shaped thin panel. As *reinforcing elements* the window-guide elements are of higher-grade tensile strength **6.1a, 6.2a, 6.1aB, 6.2aB** to:

- reinforce the U-shaped window-guides of metal sheets,
- receive parts such as hooks, keys and/or holes and
- receive elements **6.5, 6.5B, 6.6a, 6, 6b, 6.7a, 6.7b, 6.8, 6.9** (not drawn) as structural element with higher-grade tensile strength.

The elements **6.8, 6.9** ref. to **Fig.** 14 are fixedly attached to the front faces of both impact beams **1B, 7B** and window-guide element **6B**, the elements **6.6b, 6.7b** to window-guide element **6** and impact beam **7** and the elements **6.6a, 6.7a** to window-guide element **6** and between both impact beams **1, 7**.

Both window-guide elements are replaceable by an U-shaped stiff window-guide element **6, 6B**, shown in **Figs.** 2, 2A, 14 to 17. Less stiff elements **6.3, 6.3B** are normally made of panel. Alternately, very stiff window-guide element **6.3, 6.3B** serves to receive the window pane and keys **15.7**.

Window-guide element **6, 6B** provided with window-guide element **6.3, 6.3B** in the door cavity, shown in **Fig.** 2A, have open ends. To maximize the stiffness of window-guide element **6, 6B** both ends are rigidly connected to each other by window-guide element **6.4, 6.4B** in the door cavity, shown in **Figs.** 2, 14 to 17:

- after the window pane has been inserted, *or*
- by having flat profile, shown in **Fig.** 17, for the purpose of receiving window pane **60, 60B**, shown in **Fig.** 15. Later on, this window pane must be secured against falling down by protective parts.

The window-guide element **6.4, 6.4B** is useful for the accommodation of keys **15.8**. If extraneous weight is not that important for heavy cars, trucks and vans, the window-guide element fastened to the impact beams serves as members of door frame to receive keys while the window-guides of panel guides and receives the window pane.

One of the solutions for the problem case **E4** and energy-distribution to both post sections, door **8, 8B**, roof **17** and side rail **18** as well as from one vehicle side to the other vehicle side is featured in the 1st embodiment by arranging

- key **15.1** to a reinforcing element of the L-shaped A-post section, welded to reinforcing panel **17.1c** arranged along the vehicle roof and to transverse girder **17.2d** of both facing A-post sections of both vehicle sides, and the mating oblong hole to window-guide element **6.1a**;
- keys **15.1** to reinforced A-post section and the mating oblong holes to window-guide element **6.1a**;
- keys **15.2** to window-guide elements **6.1a, 6.2a** and the mating holes to reinforcing panel **17.1a** arranged along the vehicle roof; and

- keys **15.4** to the reinforcing plate of reinforcing panel **18.1** arranged along the side rail, and the mating holes to window-guide elements **6.1a, 6.2a**.

In case of large-sized door it is recommended to arrange additional keys **15.2, 15.4** to window-guide element **6.3, 6.4** and the mating holes to the reinforced vehicle roof and the reinforced side rail, respectively.

Ref. to **Fig.** 4 the 2nd embodiment consists of an interengaging assembly, the hooks of which are attached to two window-guide elements of each vehicle door and the mating rod to the vehicle roof, post sections of the door or all doors. The rod serves to reinforce the vehicle roof, sustain impact force and aid positioning on assembly, thus cutting costs. However, this embodiment needs space, which is available in large cars, trucks and vans. This embodiment is suited too for another vehicular couple comprising vehicle door/s & side rail.
The interengaging hooks **15.6** are bolted to window-guide elements **6.1a, 6.2a, 6.1aB, 6.2aB** and the mating reinforcing rod **17.1d** is arranged along the vehicle roof **17** and/or side rail **18**. When at least one pair of rods is welded to transverse girders **17.2e, 17.2f, 17.2g** of both A-, B- and C-post sections, energy can be distributed from one vehicle side to the other vehicle side in side collision, from the front to rear vehicle section of vehicle body **20** in front collision, from the rear to front vehicle section of vehicle body **20** in rear collision or to all parts of vehicle body **20** on rollover.

Ref. to **Figs.** 14, 17, 18 the 3rd embodiment consists of interengaging assemblies **30 & 6.5, 35 & 6.5B** and other interengaging assemblies **32 & 6.9, 37 & 6.9B (6.9, 6.9B** similar to **6.5**), **37 & 6.5C** for the purpose of avoiding large deformation of the edges of each door and of saving costs by exploiting the flange **21** of vehicle body **20** and the enlarged flange defined by the dotted lines "a1", "b1", "b2" and "c1". The keys **30, 32, 35, 37** are bolted to the respective reinforcing elements **21.1 to 21.5, 21.1B to 21.5B** of the flange **21** of vehicle body **20** and the corresponding holes are arranged to the housings **6.5, 6.5B** and/or auxiliary element **6.5C**, all of which are rigidly attached to the respective window-guide elements **6, 6B**, the respective elements **6.6b, 6.7b, 6.8, 6.9** (not drawn because of the similarity to **6.7b**) and/or the respective impact beams **1, 1B, 7, 7B**. The reinforcing element **21.5B** is welded to the flange and rear wheel case. The same reinforcing method can be employed to arrange a similar element **21.1** to the flange and the front wheel case.
Stiff door hinges in co-operation with impact beams **1, 7, 1B, 7B** and interengaging assemblies transmit forces of load case **I** from the front to rear vehicle section of vehicle body **20** in front collision. There is no door hinges to connect the rear door to the C-post section. To improve energy transmission from the rear to front vehicle section of vehicle body **20** in rear collision, an auxiliary element **6.5C** is attached to the impact beams **1B, 7B**. Instead of the bulky "engaging" bolt ref. to U.S. Pat. No. 3,819,228 these keys, configured in small size and distributed along the flange, neither spoil the overall design nor injure persons stepping in or out of the vehicle body.

The Technical Mechanical Method of constrained deformation is applied to secure the engagement of all vehicle parts with each other in the event of accident and to distribute impact energy thereto by means of two U-shaped extension members **17.3, 18.3**, located in common post section ref. to **Fig.** 3, whose keys **15.3, 15.3a, 15.5, 15.5a** are engaged with the mating apertures, arranged to the corresponding window-guide elements **6.2a, 6.1aB** of series-connected doors **8, 8B**, when doors are closed. This feature of the 4th embodiment prevents the disengagement of interengaging assemblies due to large inward deflection of vehicle body **20**, vehicle roof **17** or side rail **18**, above-mentioned in the problem case **E2, E3** or **E5**, when the doors are subjected to little or no deformation. As connection element of the common post section and the vehicle roof, this U-shaped extension member **17.3** is

welded to reinforcing panel **17.1b**, arranged along vehicle roof **17**, and to transverse girder **17.2c** of both facing common post sections of the vehicle sides. As connection element of the common post section and the vehicle floor this U-shaped extension member **18.3** is welded to reinforcing panel **18.1b**, arranged along the vehicle floor, and to transverse girder **18.2** of both facing common post sections of the vehicle sides. The belt case **26** can be housed in the U-shaped extension member **18.3**.

Due to the arc-travel path of the door about the mutual axis of door hinges the mating surfaces of key and receptacle of each interengaging assembly, proposed by U.S. Pat. No. 5,806,917, are configured in four tapered forms or two curved and two tapered forms, thus yielding eight tolerance zones, high manufacturing and assembling costs as well as making tight engagement impossible resulting in door detachment in accident. To resolve these problems straight (non-curved, non-inclined or non-tapered) engaging surfaces are proposed for key and receptacle. The purpose of assembling and adjusting any key, shown in **Figs.** 3, 3A, 4 and 4A, from outside of the vehicle body **20** is to substantially cut labour time and costs. Costs can be enormously lowered by using mechanical connecting parts, particularly standard parts like washer (ref. to DIN 125), hexagon socket head screw (ref. to DIN 912) etc. With the exception of **15.4a** each key **15.1 to 15.5a, 15.7, 15.8, 30 to 37** comprises a screw **15.14**, a sleeve **15.11**, a number of washers built into one spacer **15.12** and a washer with a large exterior diameter **15.13**, illustrated in **Figs.** 3A, 14 to 18. In order to ensure the engagement of key with mating hole a protrusion „x_m" and circumferential clearance „c_c", explained in the next section, must be preserved by:

- correcting the length of spacer „l" by removing or adding washers and/or
- assembling a sleeve with exterior diameter „d", washer with exterior diameter „D" and/or spacer with diameter „d_R".

If desired, the sleeve **15.11** and spacer **15.12** can be made of soundproofing material.

Each hook **15.6**, shown in **Figs.** 4 and 4A, comprises a hook **15.20** with interior diameter „d_1" and gap „s_1", smaller than „d_1", a screw **15.21**, a number of washers built into one spacer **15.22**, a coil-spring washer **15.24** and a nut **15.25**. The symbols „s_1", „d_1" and „d_2" are shown in **Fig.** 4A. In order to ensure perfect engagement of the hooks with reinforcing rod **17.1d**, having diameter „d_2" smaller than „s_1", small tolerance zones, shown in **Fig.** 4A, must be preserved by:

- assembling a hook with gap „s_1";
- assembling a rod with diameter „d_2";
- correcting the distance „l_1" by removing or adding washers; and/or
- positioning the centres of the hook hole and the reinforcing rod out of alignment.

Fig. 15 exemplifies a new feature of numerous different planes, wherein the interengaging assemblies of any vehicular couple comprising e.g. the common or B-post section and the series-connected vehicle doors **8, 8B**, operate. When the doors are closed, key **33** protrudes the mating hole by „$-x_m$" (minus sign in respect to the opposite x-direction), which is limited due to the arc-travel path of the door about the axis of door hinges. The clearances of key **33** and the mating hole are denoted by „$-y_m$" and „y_p". The protrusion „x_m", circumferential clearance „c_c" (not drawn, represented by „$-y_m$" and „y_p" in y-direction) of the mating parts of each assembly and operating plane play a significant role on tight engagement thereof in accident. In the accident, above-mentioned in the problem case **E2** or **E3**, the door becomes detached due to large circumferential clearances of all mating parts of interengaging assemblies, which operate in the same z-y plane, and large inward deflection of the vehicle body **20** or side rail **18** in the opposite x-direction, during which under the load of inertia forces of the passenger the door is opened and moved in the arc-travel path about the axis

of door hinges. Door detachment can be prevented by minimum tolerances, whereby the mating parts of interengaging assemblies of any vehicular couple, acting in the same operating plane, are governed.
In this time- and cost-saving feature against door detachment, proposed for the following embodiments, many interengaging assemblies of any vehicular couple comprising e.g. interengaging assemblies keys **32, 33, 34** & mating holes, must operate in numerous different planes, where the deformation of door **8** results in a tight engagement of keys **32, 34** with the mating holes, taken, the worse case is given, that all keys **33** fail to engage with the mating holes. The interengaging assemblies, comprising keys **32, 33, 34** & mating holes, operate in three different planes, the number of which can be increased by arranging these interengaging assemblies in the planes, which, however, are offset to each other, e.g. in offset z-y planes. The interengaging assemblies keys **35** & holes act in the fourth operating z-y plane and keys **36** & holes in the fifth operating z-x plane. Owing to this feature the minimum tolerances of "narrow" are outdated, hence, replaced by permissible tolerances of "less narrow", "far less narrow", "small" and/or "medium", thus significantly lowering the reject rate, assembly time and costs. Advantageously, a pattern of the interengaging assemblies, governed by permissible tolerances, can be issued in a table handed to assembly workers. Alternately, this pattern can be coded in the assembly program to drill, position and assemble parts thereof within the permissible tolerances. The constant, small contour clearance and the proper tolerance between door lock **248** and striker **298**, above-mentioned in the problem cases **D** and **E**, can easily be accomplished at the assembly line within short time, thus making rework as well as adjustment work superfluous. It should always be reckoned with a reject when the assembly tolerances are, unexpectedly, larger than the permissible tolerances. Adjustment work for the interengaging assemblies of the rejected car can be done outside of the assembly line, thereby preserving the production process and low reject rate. All these advantages outweigh the costs of extra material for a larger number of interengaging assemblies.
A washer **15.13** with radial teeth, serving as part of key 33, clamps in the inner region of the reinforced B-post section in any collision or on rollover. As an integral part of a screw ref. to DIN 931 Form Z the washer won't come loose on assembly.
Costs can be cut by positioning an unadjusted key between adjustable keys, such as rivet **15.4a** ref. to DIN 660, fastened to the reinforcing plate of reinforcing panel **18.1a** arranged along the side rail. However, when the number of the interengaging assemblies is limited in a low-cost configuration, for perfect interengagement the provision with keys **15.1 to 15.8, 30 to 37** without key **15.4a** is ultimately necessary.

Large total stress of the load cases **I to III** results in total deformation (buckling) of the post sections, side rail, vehicle roof and/or doors because stress of vehicle body and doors in an arbitrary real collision can never be predetermined in the research as well as in the three crash tests, above-mentioned in the problem case **E4**. To resolve such indeterminate stress the vehicular couples comprising front post section / door **8, 8B**, rear post section / door **8, 8B**, vehicle roof **17** / door **8, 8B** and side rail **18** / door **8, 8B** must be equipped with many interengaging assemblies operating in numerous different planes, such as keys **30** & holes acting in the first operating z-y plane, keys **31** & holes acting in the second operating z-x plane, key **15.2a** & hole, shown in **Fig.** 3, acting in the third operating z-y plane and in co-operation with additional interengaging assemblies, comprising keys **15.1, 15.2, 15.3, 15.3a, 15.4, 15.4a, 15.5, 15.5a, 15.6 to 15.8, 32 to 37** & receptacles, in the above-mentioned embodiments.

Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.